Alive. Active. Adaptive:
Experiential Knowledge and Emerging Materials

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Introduction

The definition of materials in design today is more extensive than ever. Designers add computational programmability to conventional materials like wood and plastics to develop material compositions that are more expressive in form and function (Vallgårda & Redström, 2007; Ishii, Lakatos, Bonanni, & Labrune, 2012). They collaborate with micro-organisms, guiding their growth and forging the conditions in which a material can be created (see for an overview, Myers, 2012; Camere & Karana, 2018). Inspired by how a plant root spreads to find light and nutrition, Diana Scherer directs the growth of plant roots to develop textile-like materials with a self-developed technique (Figure 1). The BioLogic project by the MIT Tangible Media Group (Yao et al., 2015) explores responsive clothing, whose dozens of tiny triangular flaps react to heat and humidity due to the trillion or so single-cell organisms embedded into the fabric. In the figure shown here, it is this bacteria that causes the garment to change shape within seconds or even milliseconds in response to humidity (Figure 2). Using a 3D printer with standard hardware, Morphing Matter Lab researchers (Wang et al., 2018) have replaced the machine’s open-source software with code that automatically calculates the print speed and patterns necessary to achieve particular folding angles. Their self-folding plastic objects are the first step toward products, such as flat-pack furniture, which can assume their final shape with the help of a heat gun (Figure 3).

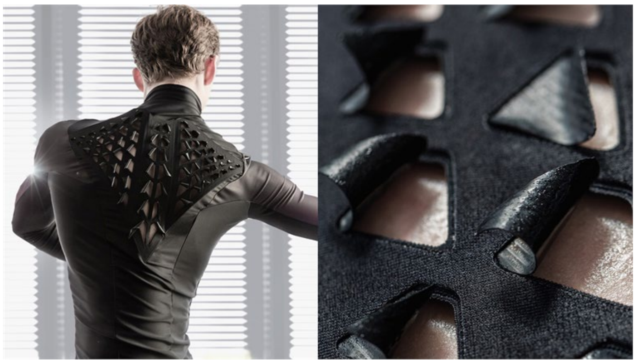

Figure 2. BioLogic, hydro-reactive fabric developed with bacteria that peels back in response to sweat and humidity, by Tangible Media Group, MIT Media Lab (photo credit: Rob Chron).

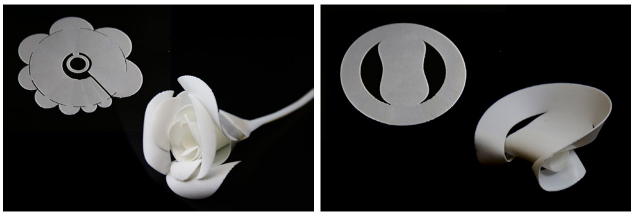

Figure 3. Programmable and 4D printed self-folding rose (left) **and chair** (right), **triggered by heat, by Morphing Matter Lab, Carnegie Mellon University.**

Figure 1. Interwoven plant roots are grown into intricate, textile-like materials, by Diana Scherer (reprinted with permission).

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The emergence of new materials as well as new approaches to designing with materials offer a broad spectrum of opportunities for achieving new material experiences in design. However, as materials become alive, active, and adaptive, and acquire new agency and interactional possibilities, how do or should designers work with them? This Special Issue offers a review of how the landscape of design is broadening with the emergence of alive, active, and adaptive materials, whether biological, chemical, or algorithmic. How do we understand and design with such materials, which have unique qualities, temporalities, and relationships with human and non-human entities? This question calls not only for different skill sets but also for a different way of understanding and mobilizing materials in design. To tackle this issue, we asked the authors for material and product design cases, examples of methods and frameworks, and theory building, which focus on the following topics:

- Designerly or artistic ways of understanding alive, active, and adaptive materials;
- Frameworks, approaches, tools, and methods to support designing (with) alive, active, and adaptive materials;
- Interdisciplinary collaboration between different disciplines (e.g., materials science and design) that open up new research and design spaces for alive, active, and adaptive materials;
- Explorations of future applications of alive, active, and adaptive materials;
- Critical views on the future of emerging materials and the implications for design research and practice;
- Design research on and reflective accounts of experience and practice with alive, active, and adaptive materials;
- Implications of alive, active, and adaptive materials in design education or other creative disciplines.

The four unique contributions to this Special Issue offer a broad yet focused overview of *Alive. Active. Adaptive* materials in relation to experiential knowledge. We deliberately gave no specific definition for the title “Alive. Active. Adaptive,” leaving it open to each author’s interpretation. As a result, the authors have been able to reframe what *Alive. Active. Adaptive* might mean within a new material landscape of design. Before delving into each unique contribution to the Special Issue, we would like to elaborate on this emergent meaning as an approach to material understanding in design.

Elvin Karana is Professor of Bio-based Art and Design at the Centre of Applied Research for Art, Design and Technology (CARADT) in the Netherlands, where she leads the “Material Incubator,” a creative research lab that aims at designing materials that incorporate living organisms and exploring their potential in fostering an alternative notion of the everyday. She received her Ph.D. in 2009 from the Delft University of Technology, where she is currently an Associate Professor in the Faculty of Industrial Design Engineering, leading the research group Materials and Fabrication Design. She has published in *Materials and Design Journal*, *International Journal of Design*, *Journal of Cleaner Production*, and *Design Issues*. She is the main editor of *Materials Experience: Fundamentals of Materials and Design* (Elsevier, 2014).

Nithikul Nimkulrat is a practitioner-researcher who intertwines research with textile practice, focusing on experiential knowledge in craft processes in the context of design research. Prior to her current appointment as a Tenured Associate Professor in Material Art and Design at OCAD University in Canada, Nithikul worked at the Estonian Academy of Arts (Estonia, 2013–2018), Loughborough University (UK, 2011–2013), and Aalto University (Finland, 2004–2010), where she earned a doctorate in 2009. Nithikul’s active involvement in international research networks can be recognized by her leading roles as the convener of the DRS Special Interest Group on Experiential Knowledge (EKSIG) and the leader of the Cumulus Association’s Fashion and Textile Working Group. She is the main editor of *Crafting Textiles in the Digital Age* (Bloomsbury Academic, 2016).

Elisa Giaccardi is Professor and Chair of Interactive Media Design at Delft University of Technology (TU Delft), where she leads the Connected Everyday Lab. Since 2018, she has also held a visiting position as Professor of Post-Industrial Design at the Umeå Institute of Design, Sweden. After conducting groundbreaking work in metadesign, and collaborative and open design processes, Elisa has in recent years focused on the challenges that a permeating digitalization brings to the field of design. Her recent research engages with “things” in new ways, with the starting point that “things” now can hold both perception and possible agency (e.g., AI), and thus “participate” in design and use in ways that previous industrially produced objects could not.

Kristina Niedderer (Ph.D., MA [RCA]) is Professor of Design at Manchester Metropolitan University. Previously, she worked at the University of Wolverhampton (2007-2018). She was originally apprenticed and worked as a goldsmith and silversmith in Germany. She then trained as a designer and design researcher in the United Kingdom. Niedderer’s research focuses on the role of design in engendering mindful interaction and behavior change. She leads the European project Designing for People with Dementia (2016-2020), MSCA grant agreement No. 691001.

Jeng-Neng Fan is Associate Professor at National Taiwan University of Science and Technology. He trained as an industrial designer and researcher in the U.S. and received his doctorate from the Harvard Graduate School of Design. His research interests target innovative materials in design, digital design and manufacturing, and designed products and variations. His design works have been recognized by many international design competitions and organizations, including the International Design Excellence Awards (IDEA) and the Red Dot Award. His recent publications have appeared as book chapters in *Cold Hibernated Elastic Memory Structure: Self-Deployable Technology and Its Applications* (CRC Press, 2018).

A Paradigm Shift for Material Understanding in Design

We propose *Alive. Active. Adaptive* as an approach to understanding materials as dynamic and open to change at both design and use time. At the time of design, they are not something that is static or that is “given” to be applied in the design process. The role of the designer calls for active participation in discovering the novel potentials of materials rather than merely translating known potentials into product applications (Barati, Karana & Hekkert, 2019). In line with Nimkulrat’s (2009) notion of materialness, the potentials of materials are constructed through situated actions (e.g., tinkering with the material, Adamson, 2007; Sundström & Höök, 2011; Nimkulrat, 2012; Rognoli, Bianchini, Maffei, & Karana, 2015; Karana, Barati, Rognoli, & Zeeuw van der Laan, 2015; Barati, 2019), through reflections (e.g., framing the material as a part of a broader context, Karana et al., 2015), and through the collaborative actions of people, materials, making (processes), and the surrounding environment (Barati, 2019). At the time of use, materials possess vibrant qualities that change and adapt over time, and that can affect the way we think, feel, and act (Giaccardi & Karana, 2015).

Petreca and her co-authors (2019) emphasize that materials are alive, active, or adaptive not only due to biological or computational qualities (e.g., materials from living organisms, or smart materials with embedded electronics). Materials can express aliveness and be active and adaptive in different ways. The authors explain, using the example of textiles, that “…before the possibility of developing alive, active, and adaptive materials emerged, textiles were already performing and relating in such a manner. …Textiles are soft materials that respond actively to being touched or otherwise moved, and are generally worn close to our body, adapting to it" (p. 9). Likewise, Hobye and Ranten (2019) define alive as a connotation for unique material expressions, in which unique qualities of computational materials adapt and come to life through interaction.

We argue that considering *Alive. Active. Adaptive* as a lens for expressiveness and performativity in *material-driven design* (Karana et al., 2015) offers unprecedented opportunities in design research and practice. It opens up a design space for designing with not only new and emerging materials that cross-fertilize the fields of biology, computation, and design but also conventional everyday materials, which can be considered or can become (Bergstrom, Clark, Frigo, Mazé, Redström, & Vallgårda, 2010) alive, active, and adaptive at both design time and use time. What might designers do with wood, for example, if they can think of it as alive and potentially able to be activated to adapt to different situations of use? How might designers design for situations in which an envisioned adaptive wood behavior could unfold? While single answers to such questions are not straightforward, a change in attitude and in the way of thinking about materials towards more unpredictable, non-linear, and open design and use situations is certainly needed.

Common to all four contributions to the Special Issue is that materials are considered as a powerful means for change in design research and practice, as well as in people's everyday experiences and ways of living. Below we provide a short overview of these contributions, which we have grouped under three main categories:

Sensitizing and Prototyping *Alive, Active, and Adaptive* Material Experiences

Two contributions to this Special Issue offer approaches and tools for understanding and communicating material experiences, in particular tactile experiences involving textiles (Petreca et al., 2019) and dynamic and performative experiences involving smart material composites (Barati et al., 2019). Petreca and her co-authors present various design tools to facilitate possible fruitful paths toward furthering our understanding of an embodied experience with textiles as alive, active, and adaptive. Their tools offer four main routes to foster "Radically Relational Experiences" with textiles:

1. *Immersion* involves developing and delivering the means (tools or methods) for designers to absorb themselves in their own touch experience with textiles.
2. *Mediation* puts forward the development of digital tools for receiving a mediated and enhanced touch experience with textiles (e.g., a haptic sleeve).
3. *Augmentation* concerns developing tools to purposely heighten specific qualities of an experience in order to provoke reactions and to evoke a more playful interaction, keeping the designers' textile exploration active and engaging them in an experience that involves the whole body.
4. *Replication* deals with tools for digitally re-creating an embodied experience as thoroughly as possible using current technologies (e.g., multi-modal iShoogle textile swatches), with the goal of inviting consideration of previously absent elements of the experience.

Barati, Karana, and Hekkert (2019) propose "Prototyping Materials Experience" as a means for developing a common understanding between scientists and designers in the collaborative development of smart material composites. Positioned in the context of the recently completed European project *Light. Touch. Matters* (LTM), this article illustrates the nature and underlying causes of the challenges that designers face in prototyping the dynamic and performative qualities of light-emitting smart material composites. The authors show how a combination of smart material demonstrators and digital support tools can overcome these challenges. They illustrate how designers have represented and prototyped LTM materials within the boundaries of three new design spaces: Luminescent Tangibles, Performable Structures, and Dynamic Light. Due to the computational properties and dynamic behavior of smart materials, which can only unfold over time, the authors suggest temporal form (Mazé & Redström, 2005) as an essential element in designing with such composites, and they propose a fourth emergent space—"Physical-Temporal Form"—situated at the intersection of the three aforementioned spaces for LTM materials.

To support the LTM collaborative team in exploring and discussing the experiential qualities of LTM materials, the authors describe how they first made the team aware of the richness of the fourth (overlapping) space at the intersection of luminescent tangible, performable structure, and dynamic light through a material demonstrator. Then they developed a hybrid sketching tool that aims to enable designers to further explore the design space beyond the limits of a specific design exemplary and to facilitate projections of a material's dynamic and performative qualities across various applications and situations.

Designing for *Alive. Active. Adaptive* Material Expressions

Bringing our attention to the complexity of algorithms, Mads Hobye and Maja Fagerberg Ranten (2019) propose five design strategies to explore the complexity of computational material as a resource for creating alive and adaptive designs:

1. *Reactiveness:* for creating interfaces that react in real-time with the user.
2. Multiple Modes: for creating multiple modes in a system that can invite different kinds of interactions.
3. *Non-linearity:* for creating internal logic without linear causality.
4. *Multiple Layers:* for combining multiple non-linear parameters with a multidimensional interaction space for participants to explore.
5. *Alive Connotations:* for creating computational patterns with anthropomorphic, zoomorphic and/or animistic expressions.

The authors emphasize that "behavioral complexity" consists of a code that deliberately intends to create complex expressions. For example, they suggest that one could quickly think of complex code with a rather simple expression, e.g., when using artificial intelligence to detect a smile, the code is complex but the output only amounts to a binary response. Through several intriguing cases, they explain how these binary responses could be designed towards more unique, complex expressions. One inspiring example presented in the paper is "The Singing Plant," an interactive sound and light installation using a living greenhouse plant as the sole interactive interface element. It is based on one of the first electronic musical instruments—the Theremin. As the authors explain: ".. *Normally the antenna is metal, but in the Singing Plant, a plant is used as the antenna. The water in the plant conducts well enough to make this possible; however, great care in calibration is required as the electrical characteristics of the plant and its soil change with varying wetness. When properly calibrated, the Theremin-plant acts as a touch and proximity sensor, which controls pitch and volume. When the plant is touched, it gives feedback in the form of sound and light. The more participants touch it, the more energetically it responds. The sound is modulated through several filters to give a richer and more variable soundscape*" (Hobje and Ranten, 2019, p. 45).

Negotiating with *Alive. Active. Adaptive* Materials

Bilge Merve Aktaş and Maarit Mäkelä (2019) zoom in on the act of making with and through materials and the constant negotiations between the maker (designer) and the material that take place in making. They review the specifications of these negotiations in their practice-led research, shedding light on the actions of the maker that occur and are shaped through material engagement. A constitutive intertwining between human intentionality and material affordances occurs in such material engagements (Glăveanu, 2014). The authors focus on the specific making practice of felting. They explain the vibrant nature and affordances of fibers in felt making and how constant negotiations happen between the maker and the material. With reference to ethnographer Mary Burkett, they explain how the flexibility of the fibers generates a movement similar to the crawling of a worm. When the wool fibers meet with warm water and the acidity of soap, the fibers in the mass become tightly entangled and form a homogenous layer of felt. They go on to explain further the role of the maker: "*The in-depth studying of material transformations in response to the bodily movements unveiled that, by its nature, wool advances its own entanglements whereas the maker aims to create her own entanglements. The way these two movements contribute to the emergence of the new artefact can thus be understood as a negotiation*" (Aktas & Mäkelä, 2019, p. 62).

Focusing on the particular action of felt making and its relationship with the material qualities of the wool in an observational study, the authors map 10 actions drawn from 16 situations. For example, in the case of ruching the fabric, the purpose was simply to bring together the fibers to create a curved shape at the half-felted stage. However, in the example presented in the article, the maker also chooses to transform the edgy corners into curved ones by both ruching and pulling the corners. The thickness is then balanced across the surface by placing additional wool, and, once the new form is established, the piece is rolled and further felted by machine to entangle the fibers in the newly-shaped corners, adding more dimension to the felted fabric. The authors provide an extensive account of the practice and the movements of the body in relation to the movements of the wool fibers, through a step-by-step analysis of the making process. They further discuss the dynamic relationship between material transformations and bodily movements, and how the authors employ negotiation as a conceptual tool to describe this process.

Conclusions

In a new and emergent design landscape in which "making," "growing," and "programming" merge, design research studies that delve into the understanding of these new practices—e.g., how the design process unfolds in designing with micro-organisms (Camere & Karana, 2018), or how novel potentials are discovered through the making process in designing with smart material composites (Barati, 2019)—are critical.

Designing with alive, active, adaptive materials or considering materials as "living" in design practice is a complex issue and requires an experiential understanding of these materials. Designers today can no longer limit themselves to the systematic method of product design practice, in which the formulation of problems and conceptualization of ideas comes first and is followed by the translation of concepts into forms, functions, and materials embodied in a final design product (Cross, 2008).

Whilst the ubiquity of new materials and newly developed technologies offers a broad spectrum of potential for designers to create design concepts and products that would not have been imaginable previously, designers today need to seek appropriate approaches, strategies, and tools to work with new materials that are variously changing, growing, or responsive to the environment and/or other materials.

This Special Issue presents just a small number of studies in which the researchers deal with different aspects of alive, active, adaptive materials. Through the accounts of their direct experience with materials in the presented design cases, we hope readers will gain a sense of the type of experiential understanding of materials, and the type of designing with and for materials experience, that is fostered by this new generation of materials and these new ways of thinking about materials.

References

1. Adamson, G. (2007). *Thinking through craft.* Oxford, UK: Berg.
2. Aktaş, B. M., & Mäkelä, M. (2019). Negotiation between the maker and material: Observations on material interactions in felting studio. *International Journal of Design, 13*(2), 57-67.
3. Barati, B. (2019). *Design touch matters: Bending and stretching the potentials of smart material composites* (Published doctoral dissertation). Delft University of Technology, Delft, Netherlands.

4. Barati, B., Karana, E., & Hekkert, P. (2019). Prototyping materials experience: Towards a shared understanding of underdeveloped smart material composites. *International Journal of Design, 13*(2), 21-38.
5. Bergström, J., Clark, B., Frigo, A., Mazé, R., Redström, J., & Vallgårda, A. (2010). Becoming materials: Material forms and forms of practice. *Digital Creativity, 21*(3), 155-172.
6. Camere, S., & Karana, E. (2018). Fabricating materials from living organisms: An emerging design practice. *Journal of Cleaner Production, 186*, 570-584.
7. Cross, N. (2008). *Engineering design methods: Strategies for product design* (4th ed.). Chichester, UK: John Wiley & Sons.
8. Giaccardi, E., & Karana, E. (2015). Foundations of materials experience: An approach for HCI. In *Proceedings of the 33rd Conference on Human Factors in Computing Systems* (pp. 2447-2456). New York, NY: ACM.
9. Glaˇveanu, V. P. (2014). *Distributed creativity: Thinking outside the box of the creative individual.* New York, NY: Springer.
10. Hobye, M., & Ranten, M. (2019). Behavioral complexity as a computational material strategy. *International Journal of Design, 13*(2), 39-53.
11. Ishii, H., Lakatos, D., Bonanni, L., & Labrune, J. -B. (2012). Radical atoms: Beyond tangible bits, toward transformable materials. *Interactions, 19*(1), 38-51.
12. Myers, W. (2012). *BioDesign: Nature, science, creativity.* London, UK: Thames and Hudson.
13. Karana E., Barati, B., Rognoli V., Zeeuw van der Laan, A., (2015). Material driven design (MDD): A method to design for material experiences. *International Journal of Design, 9*(2), 35-54.
14. Mazé, R., & Redström, J. (2005). Form and the computational object. *Digital Creativity, 16*, 7-18.
15. Nimkulrat, N. (2009). *Paperness: Expressive material in textile art from an artist's viewpoint* (Published doctoral dissertation). Alto University, Helsinki, Finland.
16. Nimkulrat, N. (2012). Hands-on intellect: Integrating craft practice into design research. *International Journal of Design, 6*(3), 1-14.
17. Petreca, B., Saito, C., Baurley, S., Atkinson, D., Yu, X., & Bianchi-Berthouze, N. (2019). Radically relational tools: A design framework to explore materials through embodied processes. *International Journal of Design, 13*(2), 7-20.
18. Rognoli, V., Bianchini, M., Maffei, S., Karana, E. (2015). DIY materials. *The Journal of Materials and Design, 86,* 692-702.
19. Sundström, P., & Höök, K. (2010). Hand in hand with the material: Designing for suppleness. In *Proceedings of the Conference on Human Factors in Computing Systems* (pp. 463-472). New York, NY: ACM.
20. Vallgårda, A., & Redström, J. (2007). Computational composites. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 513–522). ACM.
21. Wang, G., Yang, H., Yan, Z., Ulu, N. G., Tao, Y., Gu, J., Kara, L. B., & Yao, L. (2018). 4DMesh: 4D printing morphing non-developable mesh surfaces. In *Proceedings of the 31st ACM Symposium on User Interface Software and Technology* (UIST, pp. 623-635). New York, NY: ACM. DOI: https://doi.org/10.1145/3242587.3242625
22. Yao, L., Ou, J., Cheng, C.-Y., Steiner, H., Wang, W., Wang, G., & Ishii, H. (2015). BioLogic: Natto cells as nanoactuators for shape changing interfaces. In *Proceedings of the 33rd Conference on Human Factors in Computing Systems* (pp. 1-10). New York, NY: ACM. DOI: https://doi.org/10.1145/2702123.2702611